DROP TESTING FOR HIGH RELIABILITY APPLICATIONS

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Introduction

- Pb-free: reality for military applications due to part constraints
- Harsh environments have high mechanical reliability requirements
- Mechanical reliability concerns due to:
  - Pb-free COTS SMT components prone to fracture
  - Little known about the affect of rework
  - Even less known about rework of Pb-free joints with SnPb
- Robustness of electronics in harsh environments should include drop testing
  - High strain and strain rate conditions

Project Objective

- Investigate specific need of military:
  - Mechanical shock robustness of Pb-free components reworked with SnPb solder
  - Military prefers one rework solution in the field
  - Simpler than controlling both a SnPb and a Pb-free rework process

Project Overview

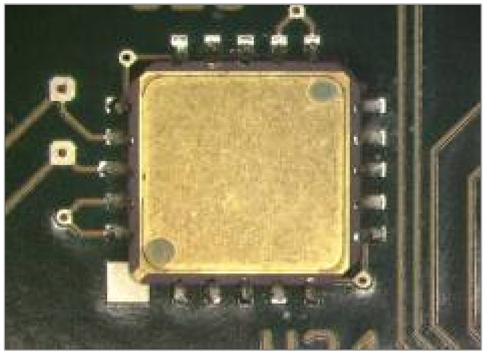
- Board-level drop shock test was performed on 29 assemblies
  - 63 parts / board
  - Parts representative of current military package styles
- Assembled on Pb-free compatible laminate with SAC 305 solder
- Metallurgical characterization
- Assemblies fixtured to drop table and subjected to 500Gs for10-20 drops
- In-situ shock response, net resistance and strain recorded
- Physical FA performed to characterize mechanical damage

Test Vehicle Details

- Test vehicle designed by:
  - Joint Group on Pollution Prevention (JG-PP)
  - National Aerospace Agency (NASA)
  - Department of Defense (DoD)
- Designed to meet IPC-6012, Class 3 requirements
  - 6 layer board with 0.5-ounce copper
  - Pb-free FR4 laminate as per IPC-4101/26
  - Minimum Tg of 170℃
  - Immersion Ag finish

Test Vehicle Components

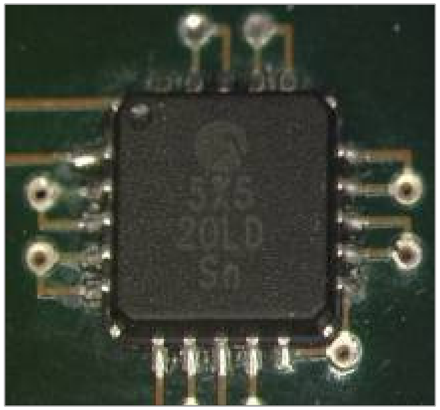
Package	Ball or Finish	Dimensions (mm x mm)	Pitch (mm)
PBGA225	SAC405 or SnPb	27 x 27	1.5
CSP100	SAC 105	10 x 10	0.8
TQFP-144	Matte Sn	20 x 20	0.5
TSOP-50	Sn	10 x 20	0.8
	SnBi	10 x 20	0.8
PDIP-20	NiPdAu	7.5 x 26	2.5
	Sn	7.5 x 26	2.5
CLCC-20	SAC305	9 x 9	0.8
QFN	Matte Sn	5 x 5	0.6



CLCC-20

TSOP-50

- Conductive: solder iron based rework on:
  - TSOP
  - TQFP
  - CLCC (tack wrap procedure)
- Conductive processes as per IPC-7711:
  - Solder wicking & vacuum extraction
  - Heat, lift part, pad cleaning
  - Part placement & fluxing
  - Drag solder replacement & cleaning
- Convective: hot air (N_2) rework for QFN, CSP and BGA devices



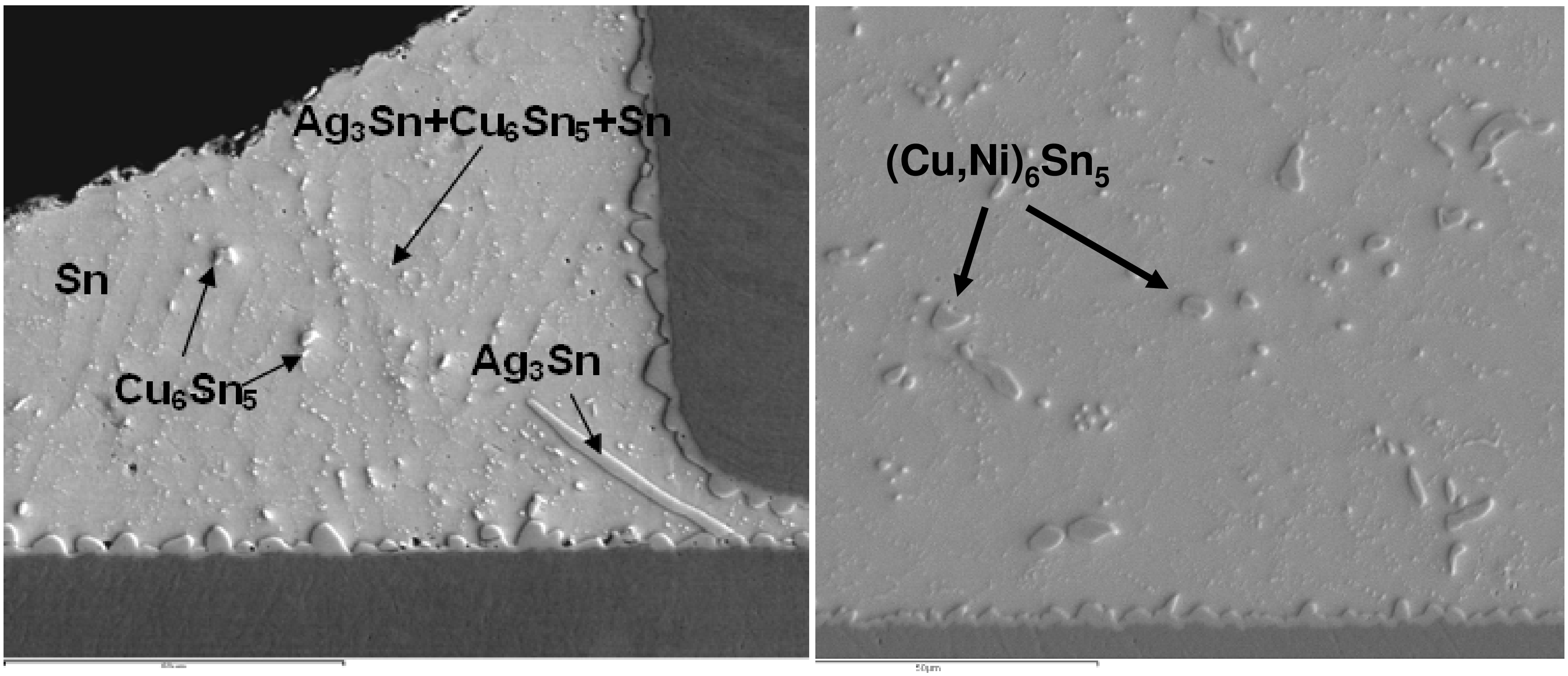
QFN

Solder Joint
Microstructure Characterization

- Investigated metallurgy of 4 parts:
  1. TQFP (Cu lead frame)
  2. TSOP (alloy 42 lead frame)
  3. QFN (Cu lead frame)
  4. BGA (SnPb balls reworked with Pb-Free paste)
- Investigated under 3 conditions:
  1. As-assembled SAC 305
  2. 1x rework with SnPb solder
  3. 2x rework with SnPb solder
- SEM / EDX was used to characterize intermetallics

TQFP-144

Microstructure Characterization

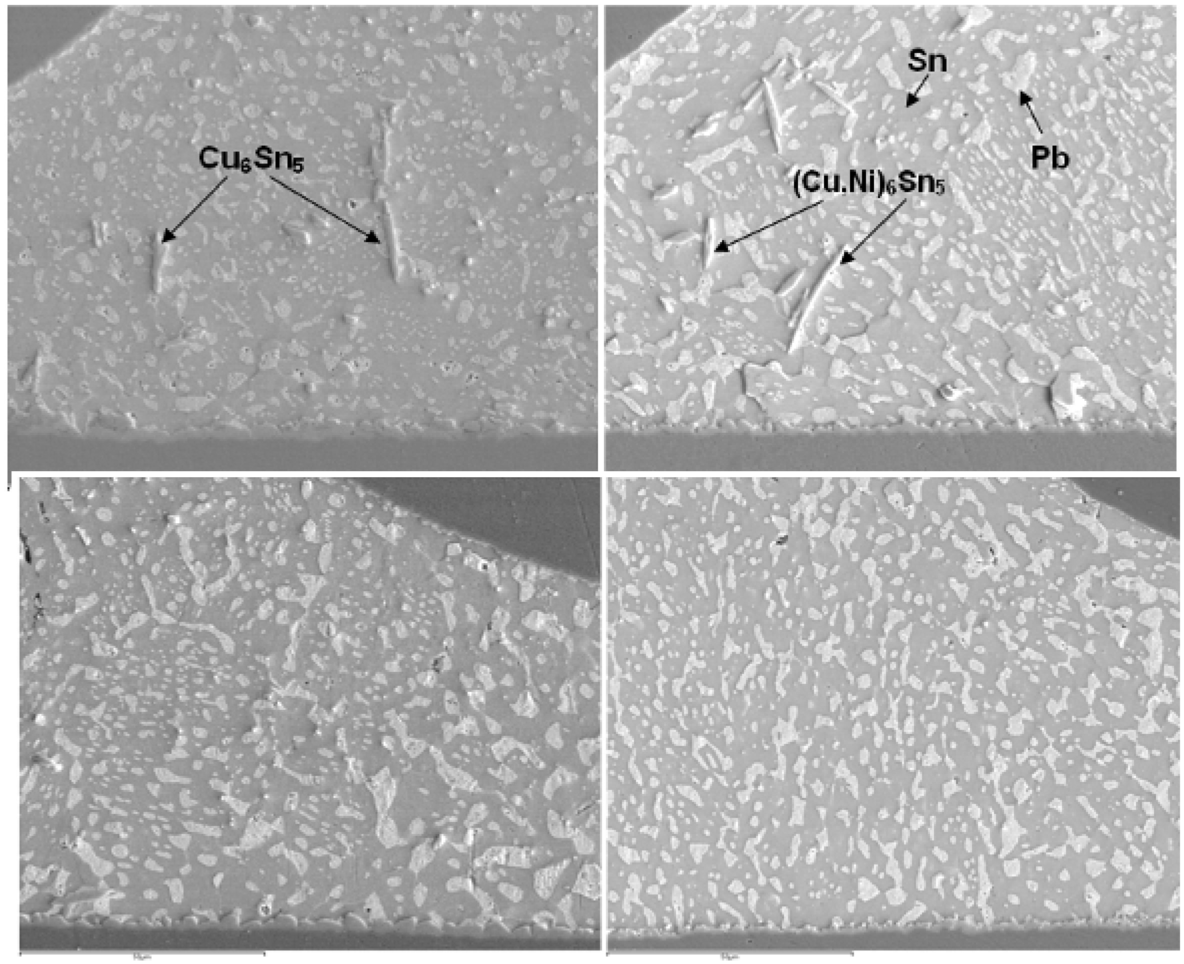


Microstructure of SAC305 solder joints before rework (SEM 1000x)
LHS = TQFP (Cu), RHS = TSOP (alloy 42)

Microstructure after Rework

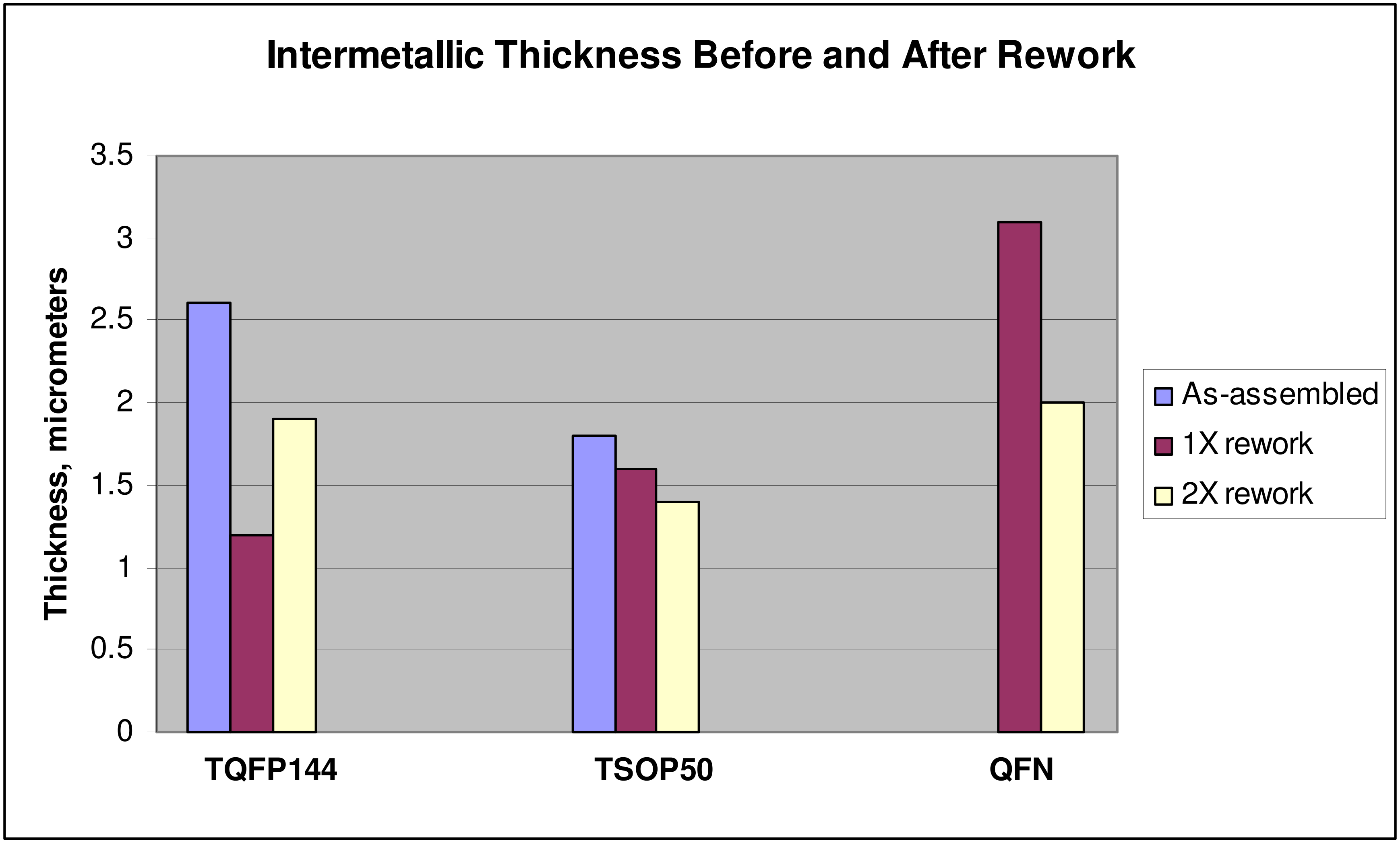
1x

2x

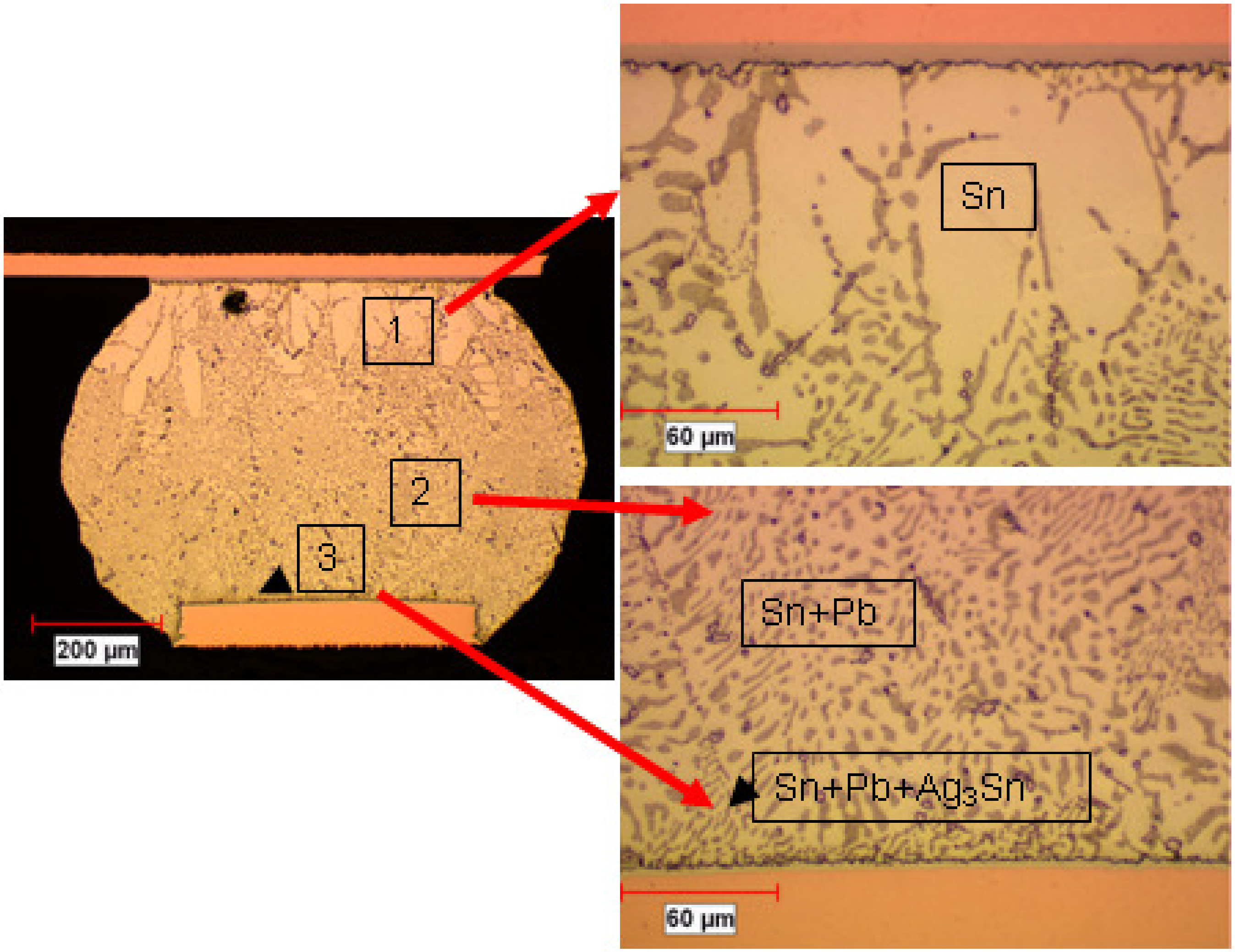


Microstructure of SAC 305 reworked using SnPb solder (SEM, 1000x)
LHS = TQFP (Cu), RHS = TSOP (alloy 42)

Microstructure Characterization



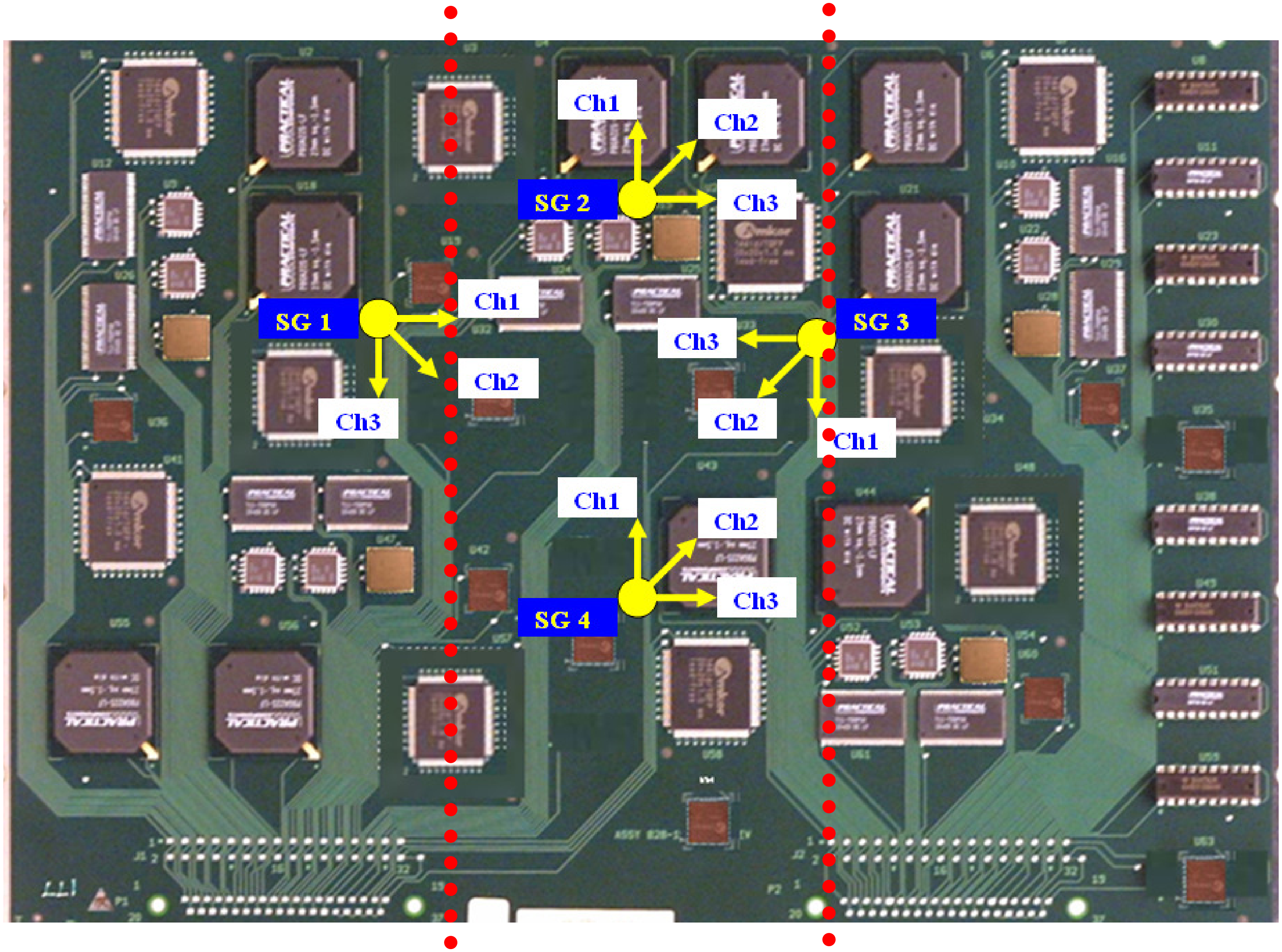
Microstructure Characterization



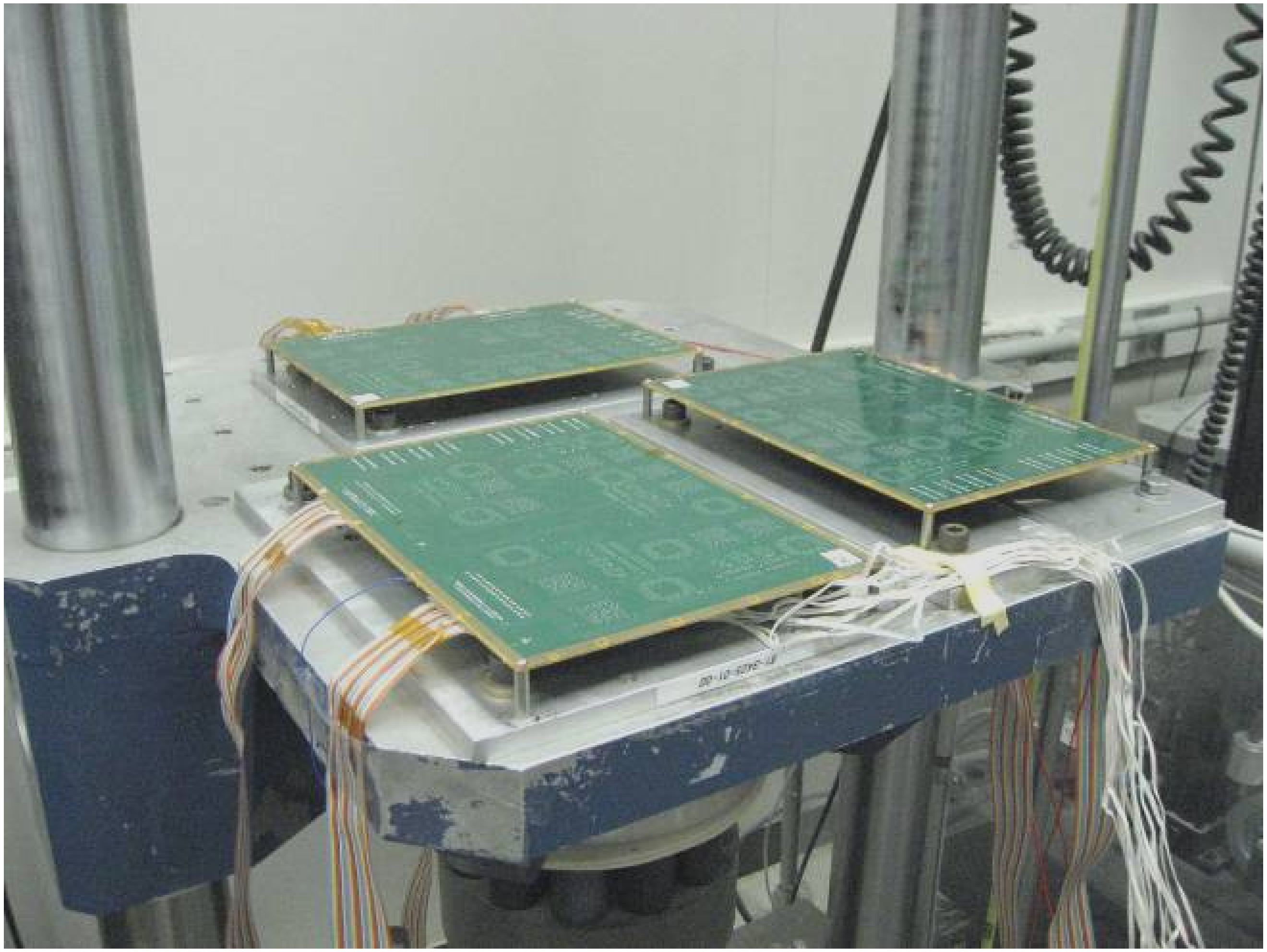
Mixed SnPb-ball/Pb-free solder joint

Drop Testing

Experimental – Drop Test



Experimental –Drop Test

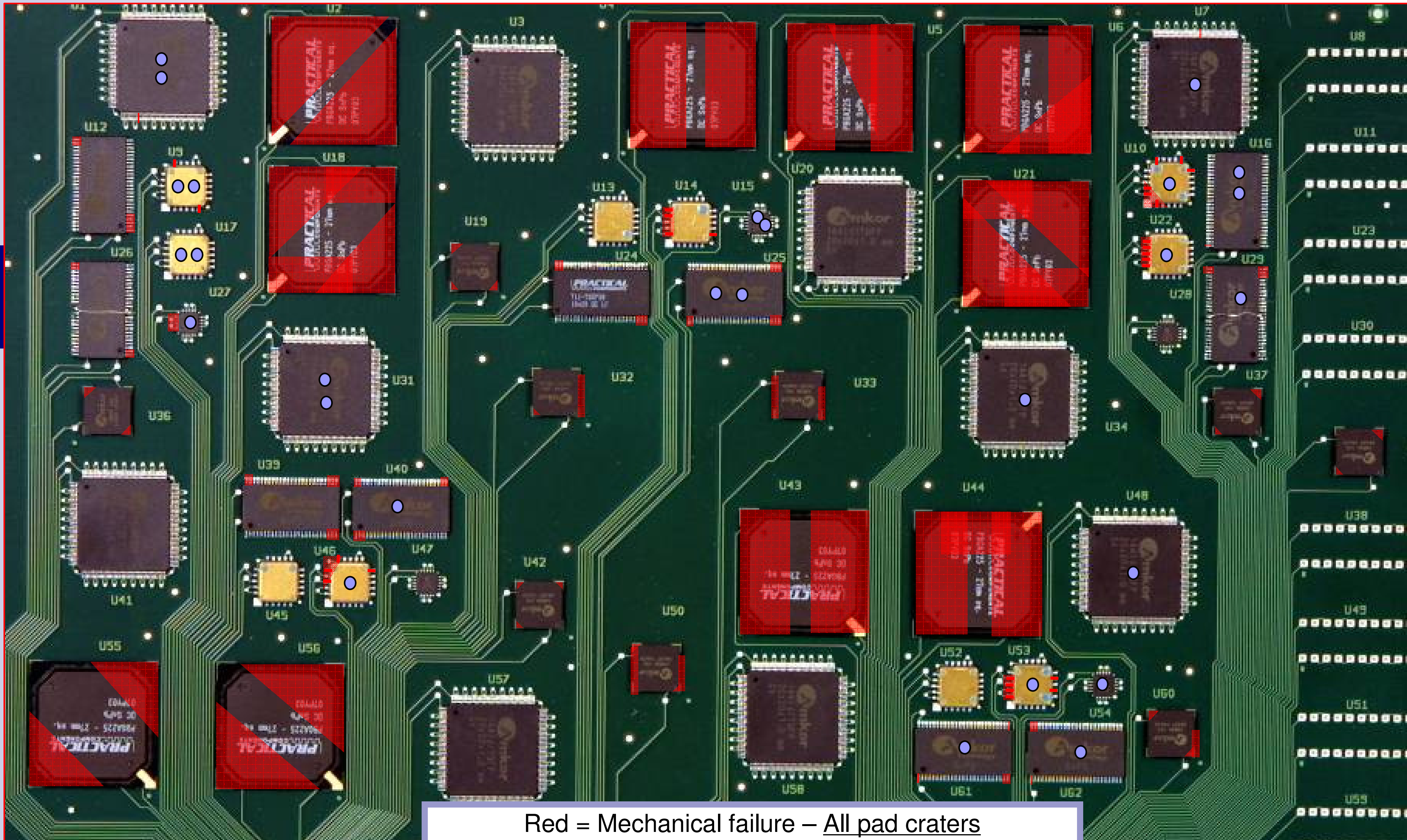


Drop Table with
Fixtured/Wired Test Vehicles

Drop Test Electrical Results

- Vast majority of electrical failures were PBGAs
  - Wide range in # of drops until failure
  - **40%** failed electrically within less than 6 drops
  - **99%** failed electrically by 20 drops
  - Pad cratering is the predominant failure mode
- All CSPs electrically passed drop testing
- Less than 1% of non-BGA components electrically failed after 20 drops

Mechanical Failures



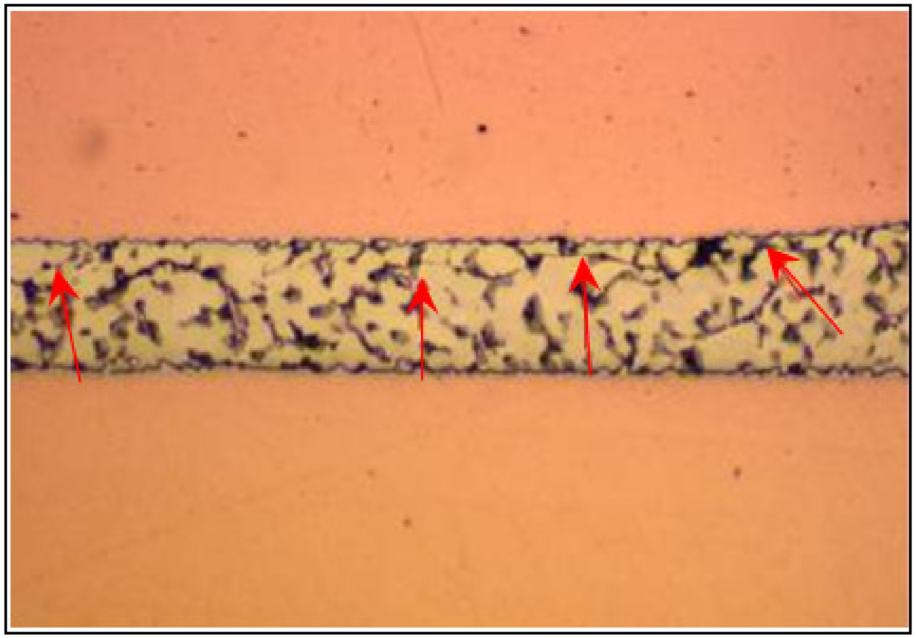
Red = Mechanical failure – All pad craters

All BGAs are Electrically Failed

No leaded parts on this board failed electrically

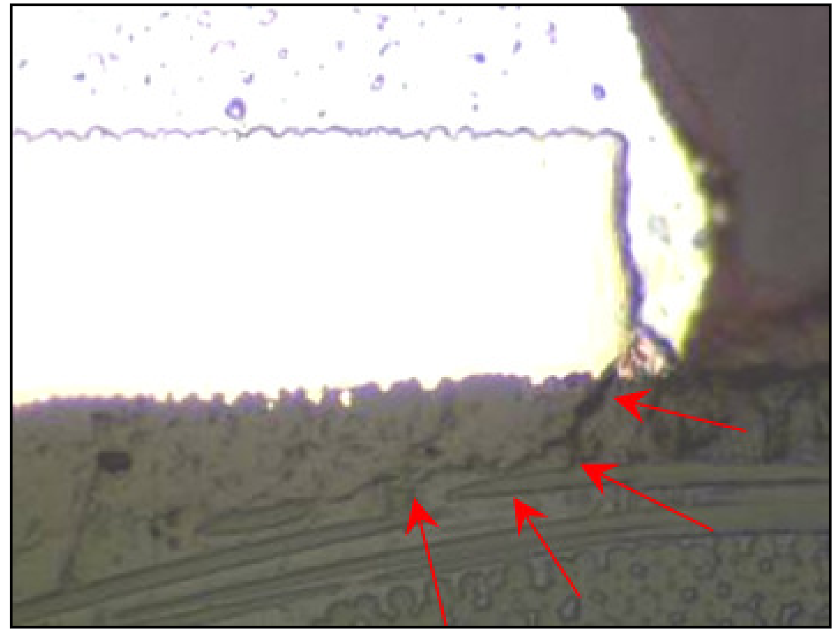
Blue Dots on Some Parts = # of SnPb Hand Reworks

Mechanical Failures Non-BGAs



Partial Solder Fracture

(QFN-20, 2x rework)



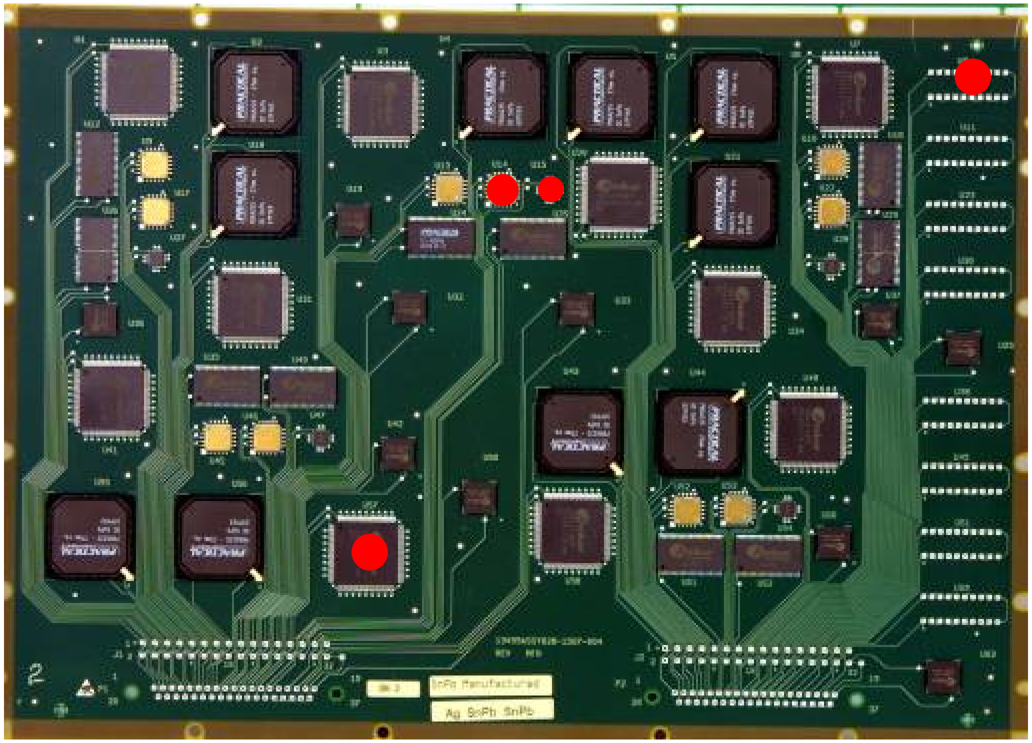
Partial Pad Crater

(QFN-20, 1x rework)

Failure Analysis of Non-BGA Failures

Electrical Fails – Non-BGAs

- Only **4** non-BGA electrical fails (< 1%)
  - Board # 1, CLCC-20, U14 was **not** reworked
  - Board # 2, TQFP 144, U57 **was** reworked 1x with SnPb
  - Board # 3, PDIP-20, U8 **was** reworked 1x with SnPb
  - Board # 4, QFN-20, U15 **was** reworked 2x with SnPb



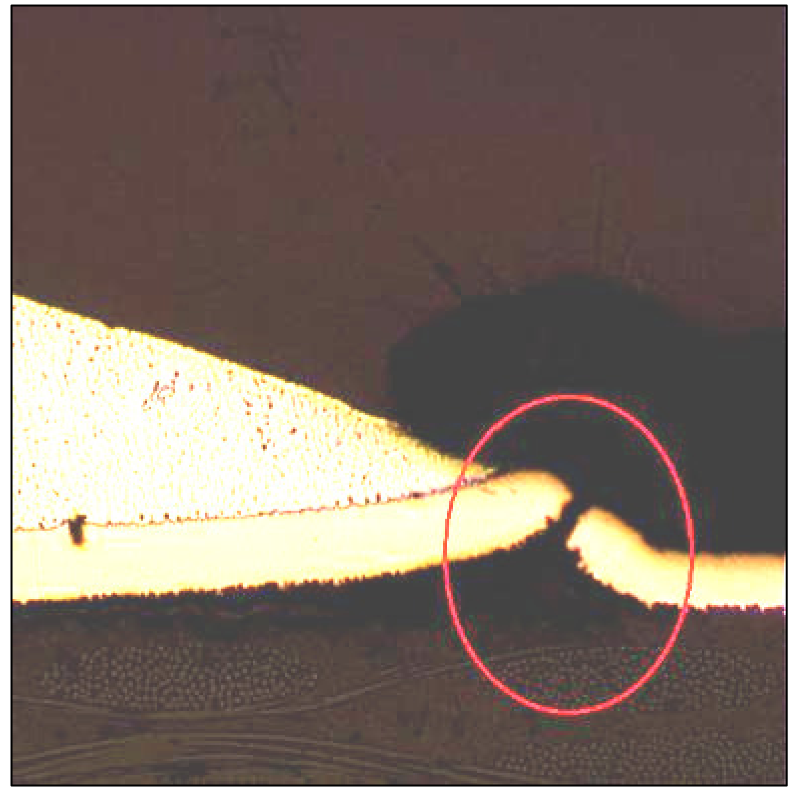
Physical FA – Non BGAs

- Eight cards selected for FA:
  - 23 parts dye & pried
  - 15 parts cross-sectioned
- Dye & pry and cross-sectioning were used to determine:
  - Failure location
  - Failure mode, and
  - Failure mechanism

FA Results – Non BGAs

Solder Fracture

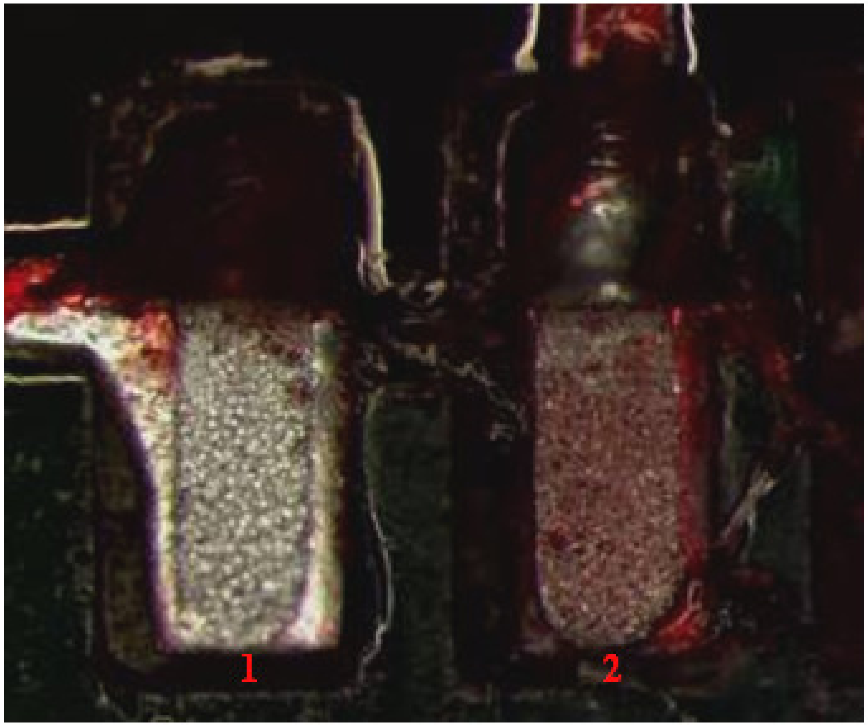
(TQFP-144)

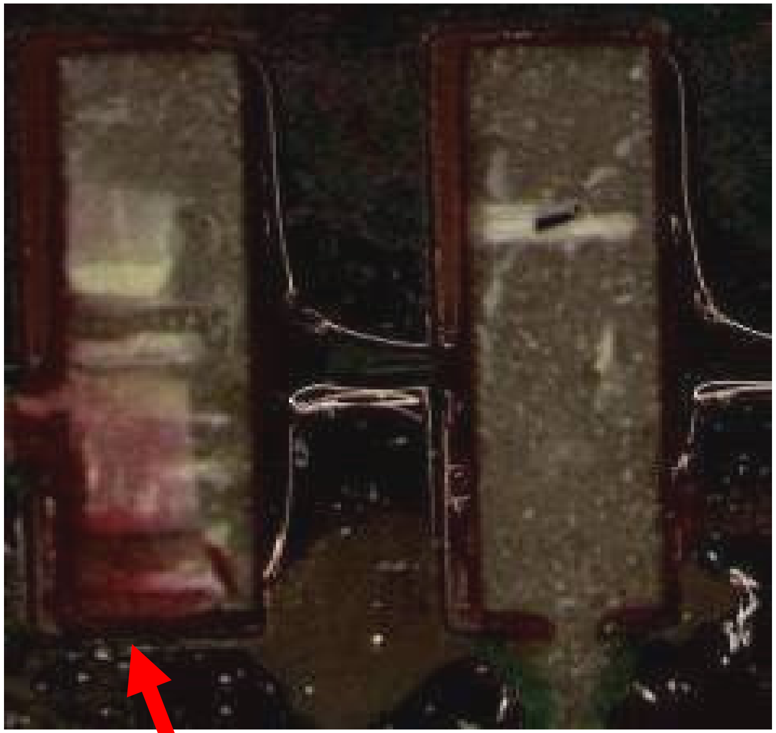


Pad Crater with Trace Break

(CLCC)

FA Results – Non-BGAs





Solder Fracture,
Full Dye Penetration
(QFN, lead 2)

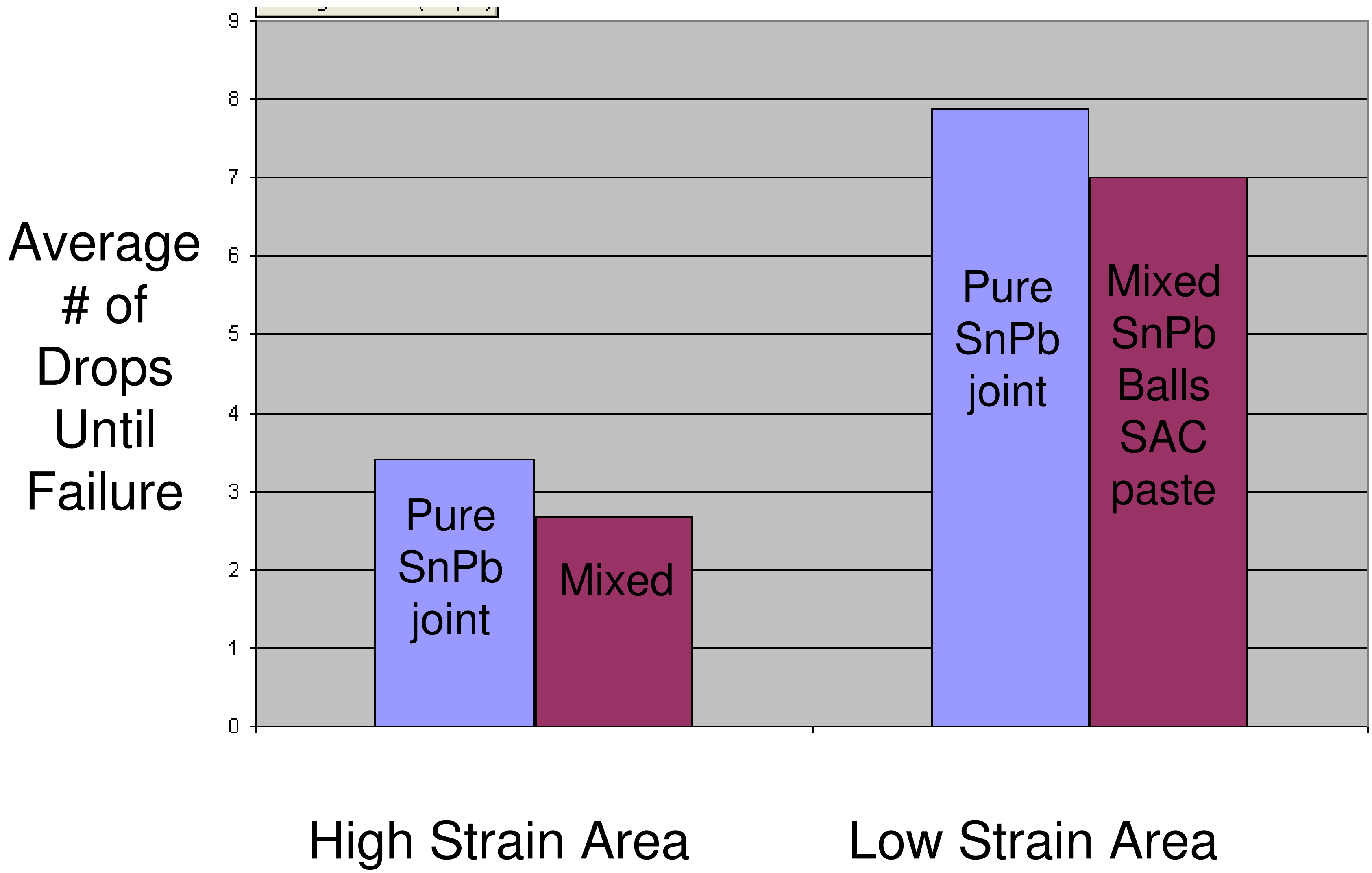
Pad Crater,
Partial Dye Penetration
(CLCC)

Summary – Non-BGAs

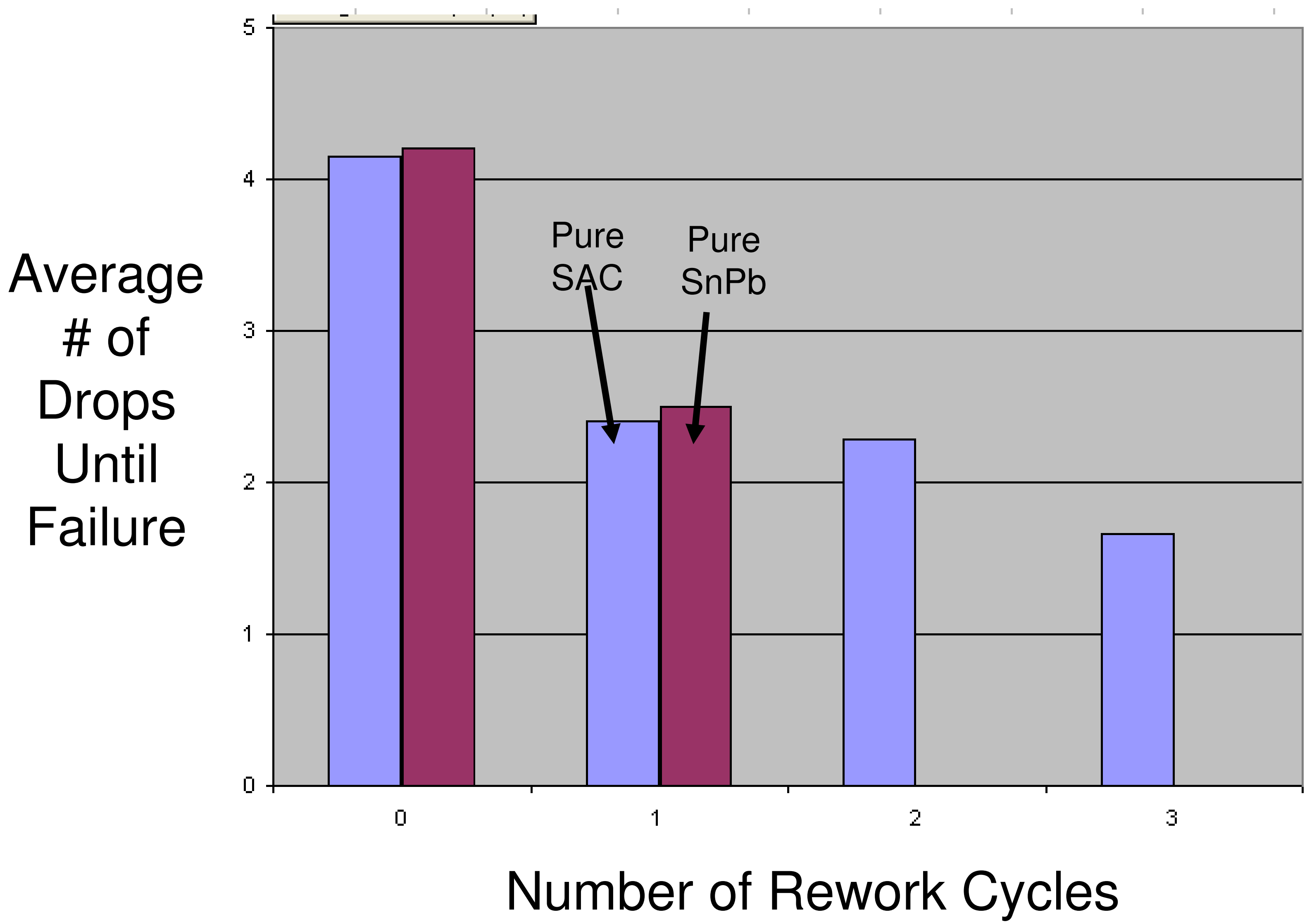
- Majority of non-BGA components survived drop testing
  - SnPb reworked parts are no less reliable than their Pb-free as-manufactured counterparts
  - In-field rework of Pb-free parts with SnPb solder should not affect mechanical robustness
- Both electrical and mechanical damage was at a minimum for non-BGA parts
  - Predominant failure mechanism was pwb-side pad cratering
- Of parts subjected to FA ~1/3 the passed electrical test had mechanical damage

Failure Analysis of BGA Failures

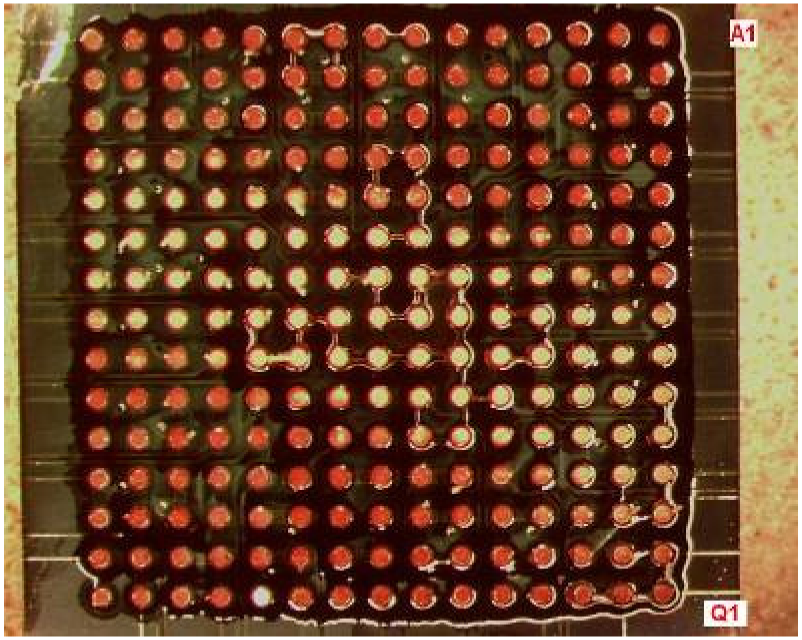
Electrical Results - BGAs



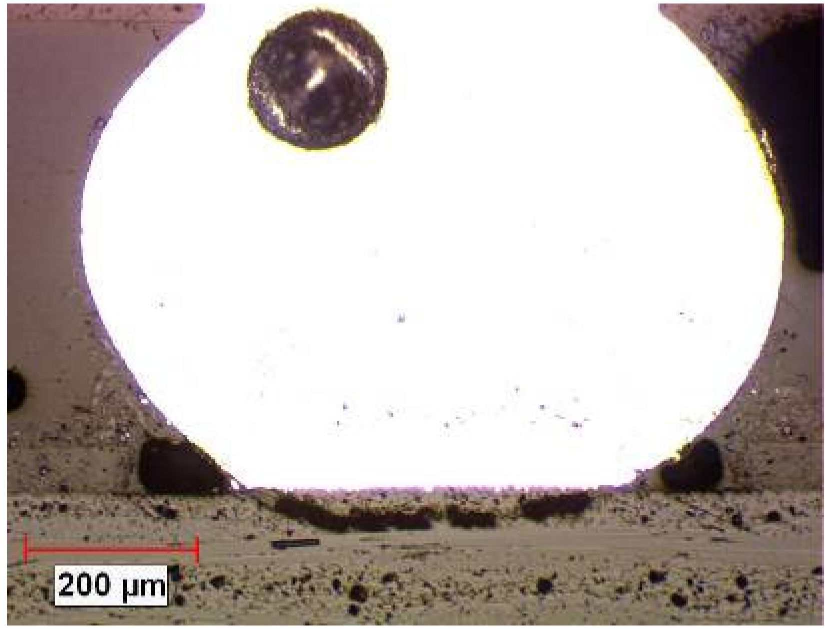
Electrical Results – BGA Rework



- Predominant failure mechanism: pad cratering



Dye and Pry



Cross-Sectioning

Summary

- For non-BGAs → No difference in drop test performance between SnPb-reworked and Pb-free joints
- Component *location* on the board plays a large role
- Component *type* plays a large role in drop test results
  - Non-BGAs and CSPs are mechanically robust package styles
  - 256 PBGAs: Mechanical damage occurs after only a few drops

Summary

- Significant mechanical damage occurs well before electrical failure
- BGAs can fail after very few drops
- Mixed solder joints fail sooner than pure SnPb BGAs
- Reworking reduces the mechanical robustness of BGAs
- Predominant failure mechanism is pad cratering

Thank You